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STOCKABILITY EQUATIONS FOR CALIFORNIA FOREST LAND

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ABSTRACT

Equations are presented for predicting the stocking capacity of commercial forest land in five geographic areas in California from site index, physical characteristics, and the presence of certain indicator plants. The equations can be used to identify areas incapable of supporting "normal" stocking. For such areas, equations provide adjustments of anticipated timber yields.

Keywords: Stocking density, indicator plants.

INTRODUCTION

In 1973, we reported on a procedure for predicting stocking capacity from multiple regression equations based on site index, elevation, and the presence of certain indicator plants (MacLean and Bolsinger 1973). The equations proved useful for (1) identifying areas incapable of supporting "normal" densities of stocking and (2) quantifying and adjusting normal yield tables to allow for this limitation on stocking capacity. The report included equations for use in Shasta and Trinity Counties, California. This paper presents equations for use in other parts of the State. We include the equation, in slightly altered form, for Shasta and Trinity Counties for the reader's convenience.

For a full understanding of the procedures, the reader should refer to the earlier paper, "Productivity on Sites with a Low Stocking Capacity" (MacLean and Bolsinger 1973).

The equations presented here predict the stocking capacity of a site expressed as a proportion of the stocking capacity of sites described in a normal yield table. For areas without stocking limitations, the equations should predict a relative stocking capacity that is within ± 20 percent of "normal." We assume that a limitation on stocking exists whenever the relative stocking capacity is less than 0.8 of normal. For such areas, normal yield table predictions of yield are discounted by the predicted relative stocking capacity. If, for example, the predicted stocking capacity of a Douglas-fir[1/] site is 0.5, then the normal yield table predictions of basal area, number of trees, and yield should all be multiplied by 0.5.

THE EQUATIONS

Five equations follow. To use the equations, select a normal yield table appropriate to the site and species. The stocking capacity of the stands described in the normal yield table can be expressed as stand density index--a measure of relative stand density developed by Reineke (1933). The normal stand density index for the yield table chosen is a variable in each equation. Normal stand density indices for yield tables commonly used in California are:

Species and Source	
Douglas-fir (Schumacher 1930)	400
Douglas-fir (McArdle et al. 1961)	370
Lodgepole pine (Dahms 1964)	460
Ponderosa pine (Meyer 1961)	365
White fir (Schumacher 1926)	565
Mixed conifer (Dunning 1933)	479

All other independent variables have a value of 1 if present and 0 if absent--except for elevation which is recorded to the nearest 100 feet, Dunning's site index (Dunning 1942) which is recorded to the nearest foot (even when estimated to the nearest 25-foot class) and universal transverse mercator (U.T.M.) coordinate distance north[2/] to the nearest 1000 meters. Plant groupings are recorded as present if any species in the group is found.

The geographic area where each equation is applicable is shown in figure 1. Area 3 bounds area 4 on the Sierra Divide. Otherwise, the boundaries conform to either county lines or the lower limits of commercial forest. Use of the equations outside these areas is not recommended.

[1/] Scientific and common names of plants are listed on page 8.

[2/] U.T.M. grids appear on U.S. Army Map Service maps and most U.S. Geological Survey quadrangles.

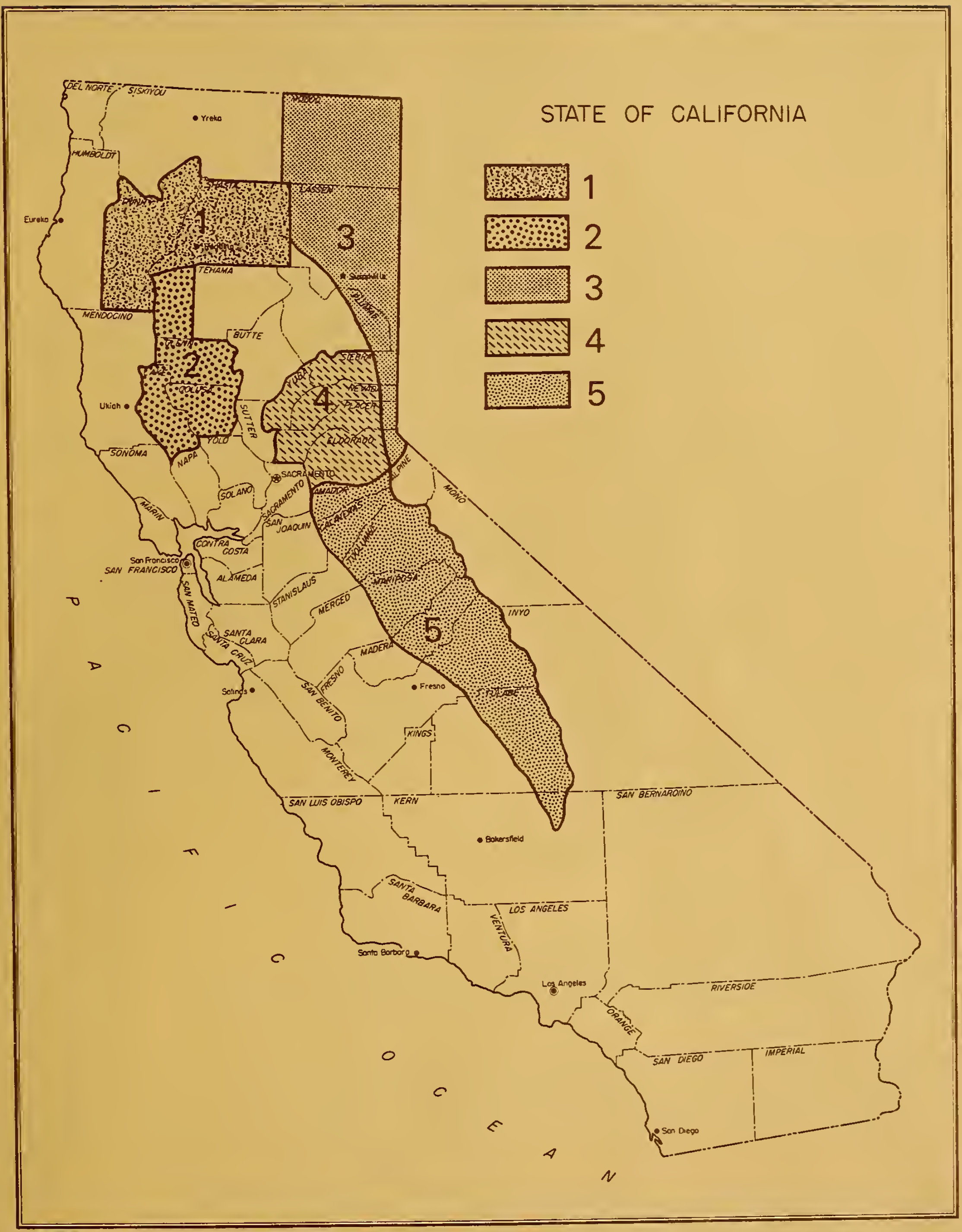

Figure 1.--State of California showing the five geographic areas sampled for this study.

AREA 1 (SHASTA AND TRINITY COUNTIES)

$$\text{Relative stocking capacity} = \frac{1}{NSDI}(-2 - 47X_1 - 84X_2 + 62X_3 + 99X_4 + 39X_5 + 92X_6 + 64X_7 + 33X_8 + 61X_9 + 32X_{10} - 44X_{11} + 0.0719X_{12} + 0.00045X_{13} - 0.0000082X_{14})$$

When: $NSDI$ = normal stand density index

X_1 = *Ceanothus cuneatus, Cercocarpus betuloides,* or *Cercocarpus ledifolius*

X_2 = *Cercis occidentalis* or *Ceanothus lemmonii*

X_3 = *Quercus garryana, Q. garryana* var. *breweri,* or *Q. wislizenii*

X_4 = *Abies magnifica*

X_5 = *Pinus lambertiana* or *Pseudotsuga menziesii*

X_6 = *Castanopsis sempervirens* or *Prunus emarginata*

X_7 = *Quercus kelloggii*

X_8 = *Pyrola picta, Trientalis latifolia,* or *Asarum* spp.

X_9 = *Chimaphila umbellata* var. *occidentalis, Pterospora andromedea,* or *Smilacina* spp.

X_{10} = *Pinus ponderosa*

X_{11} = *Ceanothus prostratus*

X_{12} = $(\text{elevation})^2$

X_{13} = $(\text{Dunning's site index})^2\ (\text{elevation})$

X_{14} = $(\text{Dunning's site index})^2\ (\text{elevation})^2$

AREA 2 (COLUSA, GLENN, LAKE, AND WESTERN TEHAMA COUNTIES)

$$\text{Relative stocking capacity} = \frac{1}{NSDI}(358 + 209X_1 - 44X_2 - 37X_3 + 49X_4 - 98X_5 - 114X_6 - 82X_7 - 55X_8)$$

When: $NSDI$ = normal stand density index

X_1 = stand basal area $\geq$ 50 percent true fir

X_2 = soil depth $\leq$ 18 inches (45.7 cm) deep

X_3 = *Arctostaphylos canescens*

X_4 = *Rosa gymnocarpa*

X_5 = *Phlox speciosa* ssp. *occidentalis*

X_6 = *Arctostaphylos manzanita* or *A. viscida*

X_7 = *Ceanothus cordulatus* or *C. integerrimus*

X_8 = *Pinus sabiniana, Quercus garryana, Q. garryana* var. *breweri,* or *Q. dumosa*

AREA 3 (MODOC, LASSEN, EASTERN PLUMAS, EASTERN SIERRA, EASTERN NEVADA, EASTERN PLACER, AND EASTERN EL DORADO COUNTIES)

$$\text{Relative stocking capacity} = \frac{1}{NSDI}(318 - 55x_1 + 74x_2 - 47x_3 + 86x_4 - 44x_5 - 61x_6 + 42x_7 + 63x_8 - 59x_9 - 99x_{10} - 44x_{11} - 77x_{12} - 115x_{13} - 35x_{14})$$

When: $NSDI$ = normal stand density index

x_1 = soil depth $\leq$ 18 inches (45.7 cm)

x_2 = *Abies magnifica*

x_3 = *Cercocarpus ledifolius* or *C. betuloides*

x_4 = *Symphoricarpos* spp.

x_5 = *Ribes cereum, R. inebrians,* or *R. roezlii*

x_6 = *Bromus tectorum* or *Stipa comata*

x_7 = *Achillea lanulosa*

x_8 = *Osmorhiza chilensis, Smilacina* spp., *Chimaphila umbellata* var. *occidentalis, Pterospora andromedea, Pyrola picta,* or *P. Picta* forma *aphylla*

x_9 = *Erysimum perenne* or *E. capitatum*

x_{10} = *Lomatium nudicaule* or *L. plummerae*

x_{11} = *Balsamorhiza* spp.

x_{12} = *Potentilla* spp.

x_{13} = *Calyptridium umbellatum, Linanthus ciliatus,* or *L. nuttallii*

x_{14} = *Agoseris heterophylla* or *A. retrorsa*

AREA 4 (YUBA, WESTERN SIERRA, WESTERN NEVADA, WESTERN PLACER, AND WESTERN EL DORADO COUNTIES)

$$\text{Relative stocking capacity} = \frac{1}{NSDI}(171 + X_1 - 142X_2 - 54X_3 - 105X_4 - 109X_5 + 127X_6 - 153X_7 + 99X_8 - 109X_9 + 0.0156X_{10})$$

When: $NSDI$ = normal stand density index

X_1 = U.T.M. grid distance north in 1000 meters minus 4200

X_2 = soil depth $\leq$ 18 inches (45.7 cm)

X_3 = *Arctostaphylos viscida*

X_4 = *Ceanothus cuneatus*

X_5 = *Rubus leucodermis*

X_6 = *Goodyera oblongifolia*

X_7 = *Polygala cornuta*

X_8 = *Viola lobata*

X_9 = *Sitanion hystrix*

X_{10} = (Dunning's site index) (elevation)

AREA 5 (AMADOR, CALAVERAS, TUOLUMNE, MARIPOSA, MADERA, FRESNO, TULARE, AND KERN COUNTIES)

$$\text{Relative stocking capacity} = \frac{1}{NSDI}(328 + 267x_1 - 112x_2 + 92x_3 + 161x_4 + 194x_5 - 91x_6)$$

When: $NSDI$ = normal stand density index

x_1 = *Pinus monticola*

x_2 = *Umbellularia californica, Quercus douglasii, Quercus garryana* var. *semota, Ceanothus cuneatus, Cercocarpus betuloides, C. ledifolius, Rhamnus crocea* ssp. *ilicifolia, Chrysothamnus* spp., *Garrya fremontii* or *Pinus sabiniana*

x_3 = *Pterospora andromedea*

x_4 = *Chimaphila menziesii, C. umbellata* var. *occidentalis, Pyrola picta, P. picta* forma *aphylla, Adenocaulon bicolor, Goodyera oblongifolia, Viola lobata, Disporum* spp., or *Smilacina* spp.

x_5 = *Pedicularis semibarbata*

x_6 = *Sitanion hystrix*

USING THE EQUATIONS

To use the equations, first search the general area to determine which indicator plants are present. Search thoroughly to find plants that are typically scattered--pinedrops, for example. Ignore plants growing on microsites such as springs, rock outcrops, or skid roads; count all others even if scarce. Also count indicator tree species that have been removed through disturbance when this is known.

RELIABILITY OF THE EQUATIONS

The relative stocking capacity equations are fractions. In each case, the numerator of the fraction is an equation which predicts what stand density index the site will support. The denominator of the fraction, the normal stand density index for the site, is derived from a normal yield table. The data in table 1 describe the reliability of the stand density index prediction equations--the numerators of the fractions.

The equations accounted for between 54 and 77 percent of the variation in stand density index capacity (coefficient of determination, table 1), and the standard error of estimate ranged from 67 to 132 stand density index points when fitted to the basic data by stepwise regression.

The equations were also tested against field data not used in the analysis. They proved as reliable in this independent test as they had in the original analysis. Predicted values were not significantly higher or lower than the measured values. The small amount of bias that did occur--21 stand density index points in area 2--was probably an accident of sampling.

Table 1.--*Reliability of equations for predicting stocking capacity for five geographic areas in California*

Reliability indicators	Area				
	1	2	3	4	5
<u>Basic data</u>:					
Number of plots to develop equation	97	81	84	88	90
Coefficient of determination (R^2)	0.77	0.58	0.68	0.69	0.54
Standard error of estimate[1/]	67	88	85	109	132
<u>Independent test</u>:					
Number of plots	70	27	72	27	37
Standard deviation of residuals[1/]	70	86	87	86	90
Amount by which estimated mean stand density index differed from actual[1/]	+6	+21	+8	+14	+6

[1/] Values are stand density index points.

PLANT NAMES[3/]

Scientific Name	Common Name
Abies concolor (Gord. & Glend.) Lindl.	white fir
Abies magnifica A. Murr.	California red fir
Achillea lanulosa Nutt.	yarrow
Adenocaulon bicolor Hook.	trail plant
Agoseris heterophylla (Nutt.) Greene.	mountain dandelion
Agoseris retrorsa (Benth.) Greene.	mountain dandelion
Arctostaphylos canescens Estw.	hoary manzanita
Arctostaphylos manzanita Parry.	Parry manzanita
Arctostaphylos viscida Parry.	whiteleaf manzanita
Asarum spp. L.	wild ginger
Balsamorhiza spp. Nutt.	balsam root
Bromus tectorum L.	cheat grass
Calyptridium umbellatum (Torr.) Greene.	pussy paws
Castanopsis sempervirens (Kell.) Dudl.	bush chinquapin
Ceanothus cordulatus Kell.	mountain whitethorn
Ceanothus cuneatus (Hook.) Nutt.	buck brush
Ceanothus integerrimus H. & A.	deer brush
Ceanothus lemmonii Parry.	Lemmon ceanothus
Ceanothus prostratus Benth.	squaw carpet
Cercis occidentalis Torr. ex Gray.	redbud
Cercocarpus betuloides Nutt. ex T. & G.	birch-leaf mountain-mahogany
Cercocarpus ledifolius Nutt.	curl-leaf mountain-mahogany
Chimaphila menziesii (R. BR. ex D. Don) Spreng.	pipsissewa
Chimaphila umbellata (L.) Barton var. *occidentalis* (Rydb.) Blake.	prince's pine
Chrysothamnus spp. Nutt.	rabbit-brush
Disporum spp. Salisb.	fairy bells
Erysimum capitatum (Dougl.) Greene.	wallflower
Erysimum perenne (Wats. ex Cov.) Abrams.	wallflower
Garrya fremontii Torr.	silk-tassel bush
Goodyera oblongifolia Raf.	rattlesnake-plantain
Linanthus ciliatus (Benth.) Greene.	linanthus
Linanthus nuttallii (Gray) Greene ex Mlkn.	linanthus
Lomatium nudicaule (Pursh) Coult. & Rose.	hog-fennel
Lomatium plummerae (Coult. & Rose) Coult. & Rose.	hog-fennel
Osmorhiza chilensis H. & A.	sweet-cicely
Pedicularis semibarbata Gray.	lousewart
Phlox speciosa Pursh ssp. *occidentalis* (Durand) Wherry.	phlox
Pinus contorta Dougl.	lodgepole pine
Pinus lambertiana Dougl.	sugar pine
Pinus monticola Dougl.	western white pine
Pinus ponderosa Laws.	ponderosa pine
Pinus sabiniana Dougl.	Digger pine

[3/] Names of trees according to Little (1953); scientific names of grasses, herbs, and shrubs, Munz and Keck (1970).

Polygala cornuta Kell.	milkwort
Potentilla spp. L.	cinquefoil
Prunus emarginata (Dougl.) Walp.	bitter cherry
Pseudotsuga menziesii (Mirb.) Franco	Douglas-fir
Pterospora andromedea Nutt.	pinedrops
Pyrola picta Sm.	shinleaf
Pyrola picta forma *aphylla* (Sm.) Camp.	leafless pyrola
Quercus douglasii Hook & Arn.	blue oak
Quercus dumosa Nutt.	California scrub oak
Quercus garryana Dougl.	Oregon white oak
Quercus garryana Dougl. var. *breweri* (Engelm. in Wats.) Jeps.	Brewer oak
Quercus garryana Dougl. var. *semota* Jeps.	Kaweah oak
Quercus kelloggii Newb.	California black oak
Quercus wislizenii A. DC.	interior live oak
Rhamnus crocea Nutt. in T. & G. ssp. *ilicifolia* (Kell.) C. B. Wolf.	hollyleaf buckthorn
Ribes cereum Dougl.	squaw currant
Ribes inebrians Lindl.	squaw currant
Ribes roezlii Regel.	Sierra gooseberry
Rosa gymnocarpa Nutt. in T. & G.	wood rose
Rubus leucodermis Dougl. ex T. & G.	western raspberry
Sitanion hystrix (Nutt.) J. G. Sm.	bottle-brush squirrel-tail grass
Smilacina spp. Desf.	false solomon's-seal
Stipa comata Trin. & Rupr.	needle and thread grass
Symphoricarpos spp. Duhamel.	snowberry
Trientalis latifolia Hook.	star-flower
Umbellularia californica (Hook. & Arn.) Nutt.	California-laurel
Viola lobata Benth.	pine violet

LITERATURE CITED

Dahms, Walter G.
1964. Gross and net yield tables for lodgepole pine. USDA For. Serv. Res. Pap. PNW-8, 14 p., illus. Pac. Northwest For. & Range Exp. Stn., Portland, Oreg.

Dunning, Duncan
1942. A site classification for the mixed conifer selection forest of the Sierra Nevada. Calif. For. & Range Exp. Stn. USDA For. Serv. Res. Note 28, 21 p., illus. Berkeley, Calif.

Dunning, Duncan, and L. H. Reineke
1933. Preliminary yield tables for second-growth stands in the California pine region. U.S. Dep. Agric. Tech. Bull. 354, 23 p., illus.

Little, Elbert L., Jr.
1953. Checklist of native and naturalized trees of the United States (including Alaska). U.S. Dep. Agric. Agric. Handb. 41, 472 p.

McArdle, Richard E., W. H. Meyer, and D. Bruce
1961. The yield of Douglas-fir in the Pacific Northwest. U.S. Dep. Agric. Tech. Bull. 201 (rev.), 74 p., illus.

MacLean, Colin D., and Charles L. Bolsinger
1973. Estimating productivity on sites with a low stocking capacity. USDA For. Serv. Res. Pap. PNW-152, 18 p., illus. Pac. Northwest For. & Range Exp. Stn., Portland, Oreg.

Meyer, Walter H.
1961. Yield of even-aged stands of ponderosa pine. U.S. Dep. Agric. Tech. Bull. 630 (rev.), 59 p., illus.

Munz, Philip A., and David D. Keck
1970. A California flora. 1,681 p., illus. Berkeley: Univ. Calif. Press.

Reineke, L. H.
1933. Perfecting a stand density index for even-aged forests. J. Agric. Res. 46: 627-638, illus.

Schumacher, Francis X.
1926. Yield, stand and volume tables for white fir in the California pine region. Calif. Agric. Exp. Stn. Bull. No. 407, 26 p., illus. Univ. Calif., Berkeley.

Schumacher, Francis X.
1930. Yield, stand and volume tables for Douglas-fir in California. Calif. Agric. Exp. Stn. Bull. No. 491, 41 p., illus. Univ. Calif., Berkeley.

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